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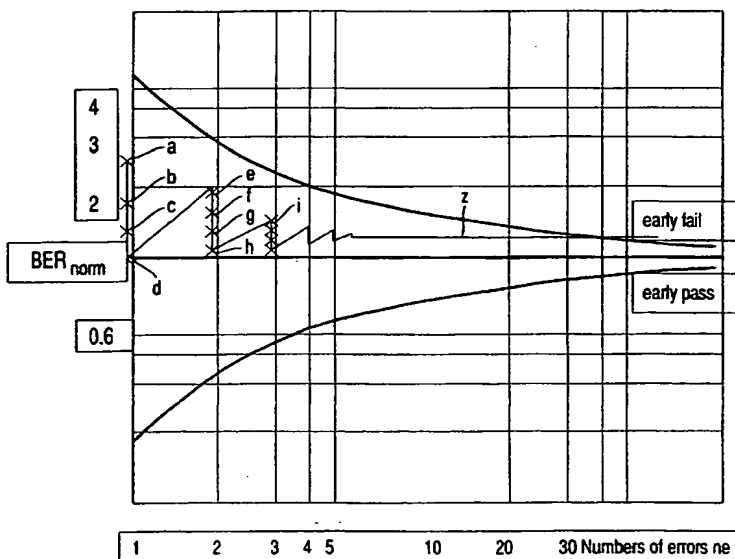
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(54) Title: METHOD FOR TESTING THE ERROR RATIO OF A DEVICE

BER limit = 0.2 (1/5) Actual BER = 0.25 (1/4)

Number of sample,	1	2	3	4	5	6	7	8	9	10 etc...
Sequence, 0: correct, 1: error	0	1	0	0	0	1	0	0	0	1
BER		1/2	1/3	1/4	1/5	2/6	2/7	2/8	2/9	3/10
BER norm		5/2	5/3	5/4	5/5	10/6	10/7	10/8	10/9	15/10



(57) Abstract: A method for testing the (Bit) Error Ratio BER of a device against a maximal allowable (Bit) Error Ratio  $BER_{limit}$  with an early pass and/or early fail criterion, whereby the early pass and/or early fail criterion is allowed to be wrong only by a small probability  $D$ .  $n_s$  bits of the output of the device are measured, thereby  $n_e$  erroneous bits of these  $n_s$  bits are detected.  $PD_{high}$  and/or  $PD_{low}$  are obtained, whereby  $PD_{high}$  is the worst possible likelihood distribution and  $PD_{low}$  is the best possible likelihood distribution containing the measured  $n_e$  erroneous bits with the probability  $D$ . The average numbers of erroneous bits  $NE_{high}$  and  $NE_{low}$  for  $PD_{high}$  and  $PD_{low}$  are obtained.  $NE_{high}$  and  $NE_{low}$  are compared with  $NE_{limit} = BER_{limit} \times n_s$ . If  $NE_{limit}$  is higher than  $NE_{high}$  or  $NE_{limit}$  is lower than  $NE_{low}$  the test is stopped.

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## Method for testing the Error Ratio of a Device

The application is related to testing the (Bit) Error Ratio of a device, such as a digital receiver for mobile phones.

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Concerning the state of the art, reference is made to US 5,606,563. This document discloses a method of determining an error level of a data channel comprised of receiving channel parity error data indicating when bit errors occur within a set of data carried on the channel (channel error events), successively integrating the channel error events data over successive accumulation periods, comparing the integrated channel error events data with a threshold, and indicating an alarm in the event the integrated channel error events data exceeds the threshold.

Testing digital receivers is two fold: The receiver is offered a signal, usually accompanied with certain stress conditions. The receiver has to demodulate and to decode this signal. Due to stress conditions the result can be partly erroneous. The ratio of erroneously demodulated to correctly demodulated bits is measured in the Error Ratio test. The Bit Error Ratio BER test or more general any error rate test, for example Frame Error Ratio FER, Block Error Ratio BLER each comprising a Bit Error test, is subject of this application.

BER testing is time consuming. This is illustrated by the following example: a frequently used BER limit is 0.001. The bitrate frequently used for this test is approx. 10kbit/s. Due to statistical relevance it is not enough to observe 1 error in 1000 bits. It is usual to observe approx. 200 errors in 200 000 bits. This single BER test lasts 20 seconds. There are combined tests which contain this single BER test several times, e.g. the receiver blocking test. Within this test the single BER test is repeated 12750 times with different stress conditions. Total test time here is more than 70h. It is known in the state of the art to fail the DUT (Device Under Test) early



only, when a fixed number of errors as 200 errors are observed before 200 000 bits are applied. (Numbers from the example above).

- 5 It is the object of the present application to propose a method for testing the Bit Error Ratio of a device with reduced test time, preserving the statistical relevance.

The object is solved by the features of claim 1 or claim 4.

10

- According to the present invention, the worst possible likelihood distribution  $PD_{high}$  and/or the best possible likelihood distribution  $PD_{low}$  are obtained by the formulas given in claim 1 and 4, respectively. From these likelihood  
15 distributions, the average number  $NE_{high}$  or  $NE_{low}$  is obtained and compared with the limit  $NE_{limit}$ , respectively. If the limit  $NE_{limit}$  is higher than the average number  $NE_{high}$  or smaller than the average number  $NE_{low}$ , the test is stopped and it is decided that the device has early passed or early  
20 failed, respectively.

The dependent claims contain further developments of the invention.

- 25 The Poisson distribution preferably used for the present invention, is best adapted to the BER problem. The nature of the Bit Error occurrence is ideally described by the binomial distribution. This distribution, however, can only be handled for small number of bits and errors. For a  
30 high number of bits and a low Bit Error Ratio the binomial distribution is approximated by the Poisson distribution. This prerequisite (high number of bits, low BER) is ideally fulfilled for normal Bit Error Rate testing (BER limit 0.001) as long as the DUT is not totally broken (BER 0.5).  
35 The application proposes to overcome problems with the discrete nature of the Poisson distribution. With the same method an early pass condition as well as an early fail condition is derived.



An embodiment of the invention is described hereafter. In the drawings

- Fig. 1 shows a diagram to illustrate the inventive method,
- Fig. 2 shows the referenced Bit Error Ratio  $ber_{norm}$  as a function of the measured errors  $ne$ ,
- Fig. 3 shows a diagram to illustrate a measurement using a first embodiment of the inventive method,
- Fig. 4 shows a diagram to illustrate a measurement using a second embodiment of the inventive method and
- Fig. 5 shows a diagram illustrating the position at the end of the test using the first embodiment of the inventive method as a function of probability.
- In the following, the early fail condition and the early pass condition is derived with mathematical methods.
- Due to the nature of the test, namely discrete error events, the early stop conditions are declared not valid, when fractional errors  $< 1$  are used to calculate the early stop limits. The application contains proposals, how to conduct the test at this undefined areas. The proposals are conservative (not risky). A DUT on the limit does not achieve any early stop condition. The application proposes to stop the test unconditioned at a specific number  $K$  (for example 200 bit) errors. As this proposal contains a pseudo paradox, an additional proposal to resolve this pseudo paradox is appended.
- Based on a single measurement, a confidence range  $CR$  around this measurement is derived. It has the property that with high probability the final result can be found in this range.



The confidence range CR is compared with the specified BER limit. From the result a diagram is derived containing the early fail and the early pass condition.

- 5 With a finite number of samples  $n_s$  of measured bits, the final Bit Error Ratio BER cannot be determined exactly. Applying a finite number of samples  $n_s$ , a number of errors  $n_e$  is measured.  $n_e/n_s = \text{ber}$  is the preliminary Bit Error Ratio.

10

In a single test a finite number of measured bits  $n_s$  is applied, and a number of errors  $n_e$  is measured.  $n_e$  is connected with a certain differential probability in the Poisson distribution. The probability and the position in the distribution conducting just one single test is not known.

Repeating this test infinite times, applying repeatedly the same  $n_s$ , the complete Poisson distribution is obtained. The average number (mean value) of errors is  $NE$ .  $NE/n_s$  is the final BER. The Poisson distribution has the variable  $n_e$  and is characterised by the parameter  $NE$ , the average or mean value. Real probabilities to find  $n_e$  between two limits are calculated by integrating between such limits. The width of the Poisson distribution increases proportional to  $\text{SQR}(NE)$ , that means, it increases absolutely, but decreases relatively.

In a single test  $n_s$  samples are applied and  $n_e$  errors are measured. The result can be a member of different Poisson distributions each characterized by another parameter  $NE$ . Two of them are given as follows:

The worst possible distribution  $NE_{\text{high}}$ , containing the measured  $n_e$  with the probability  $D_1$ , is given by

$$D_1 = \int_0^{n_e} PD_{\text{high}}(NE_{\text{high}}, ni) dni \quad (1)$$



In the example  $D_1$  is  $0.002=0.2\%$   $PD_{high}$  is the wanted Poisson distribution with the variable  $ni$ .  $ne$  is the measured number of errors.

- 5 The best possible distributions  $NE_{low}$ , containing the measured  $ne$  with the probability  $D_2$  is given by

$$D_2 = \int_{ne}^{\infty} PD_{low}(NE_{low}, ni) dni \quad (2)$$

10

In the example  $D_2$  is equal  $D_1$  and it is  $D = D_1 = D_2 = 0.002=0.2\%$ .

- 15 To illustrate the meaning of the range between  $NE_{low}$  and  $NE_{high}$  refer to Fig. 1. Fig. 1 shows the likelihood density  $PD$  as a function of the measured number of errors  $ne$ . In the example, the actual detected number of errors  $ne$  within the measured sample of  $ns$  bits is 10. The likelihood  
 20 distribution of the errors is not known. The worst possible likelihood distribution  $PD_{high}$  under all possible likelihood distributions as well as the best possible likelihood distribution  $PD_{low}$  under all possible likelihood distributions are shown. The worst possible likelihood  
 25 distribution  $PD_{high}$  is characterized in that the integral from 0 to  $ne = 10$  gives a total probability of  $D_1 = 0.002$ . The best possible likelihood distribution  $PD_{low}$  is characterized in that the integral from  $ne = 10$  to  $\infty$  gives a total probability of  $D_2 = 0.002$ . In the preferred  
 30 embodiment  $D_1$  is equal to  $D_2$ , i.e.  $D_1 = D_2 = 0.002 = 0.2\%$ . After having obtained the likelihood distribution  $PD_{high}$  and  $PD_{low}$  from formulas (1) and (2), the average values or mean values  $NE_{high}$  for the likelihood distribution  $PD_{high}$  and  $NE_{low}$  for the likelihood distribution  $PD_{low}$  can be obtained.  
 35 The range between the mean value  $NE_{low}$  and  $NE_{high}$  is the confidence range  $CR$  indicated in Fig. 1.



In the case the measured value  $ne$  is a rather untypical result (in the example just 0.2% probability) nevertheless the final result  $NE$  can still be found in this range, called confidence range  $CR$ .

5

The probabilities  $D_1$  and  $D_2$  in (1) and (2) can be independent, but preferable they are dependent and equal ( $D = D_1 = D_2$ ).

- 10 For the Poisson distribution  $NE_{low}$  and  $NE_{high}$  can be obtained. With the formulas (3) and (4) respectively the inputs are the number of errors  $ne$ , measured in this test and the probabilities  $D$  and  $C = 1 - D$ . The Output is  $NE$ , the parameter describing the average of the Poisson
- 15 distribution.

The following example is illustrated in Fig. 1 ( $D = D_1 = D_2$ ):

$$20 \quad NE_{low} = \frac{qchisq(D, 2 \cdot ne)}{2} \quad (3)$$

$$NE_{high} = \frac{qchisq(C, 2(ne + 1))}{2} \quad (4)$$

Example:

25

Number of errors:  $ne=10$

Probability:  $D=0.002$   $C=0.998$

Result:

30

$NE_{low} = 3.26$

$NE_{high} = 22.98$

Interpretation:

- 35 Having measured  $ne=10$  errors in a single test, then with a low probability  $D=0.002$  the average number of errors  $NE$  in this test is outside the range from 3.26 to 22.98 or with a



high probability  $C=0.998$  inside this range from 3.26 to 22.98.

Such as the width of the Poisson distribution, the confidence range CR increases proportional to  $\text{SQR}(ne)$ , that means, it increases absolutely, but decreases relatively.

If the entire confidence range CR, calculated from a single result  $ne$ , is found on the good side ( $NE_{\text{limit}} > NE_{\text{high}}$ ) of the specified limit  $NE_{\text{limit}}$  we can state: With high probability  $C$ , the final result  $NE$  is better than the limit  $NE_{\text{limit}}$ . Whereby  $NE_{\text{limit}}$  is given by

$$NE_{\text{limit}} = BER_{\text{limit}} \cdot ns \quad (5)$$

15

and  $BER_{\text{limit}}$  is the Bit Error Rate allowable for the device and obtained by an ideal long test with an infinite high number of bit samples  $ns$ .

20 If the entire confidence range CR, calculated from a single result  $ne$ , is found on the bad side ( $NE_{\text{limit}} < NE_{\text{low}}$ ) of the specified limit  $NE_{\text{limit}}$  we can state: With high probability  $C$ , the final result  $NE$  is worse than the limit.

25 With each new sample and/or error a new test is considered, reusing all former results. With each new test the preliminary data for  $ns$ ,  $ne$  and  $ber$  is updated. For each new test the confidence range CR is calculated and checked against the test limit  $NE_{\text{limit}}$ .

30

Once the entire confidence range CR is found on the good side of the specified limit ( $NE_{\text{limit}} > NE_{\text{high}}$ ), an early pass is allowed. Once the entire confidence range CR is found on the bad side of the specified limit ( $NE_{\text{limit}} < NE_{\text{low}}$ ) an early fail is allowed. If the confidence range CR is found on both sides of the specified limit ( $NE_{\text{low}} < NE_{\text{limit}} < NE_{\text{high}}$ ), it is evident neither to pass nor to fail the DUT early.



Fig. 1 illustrates the above conditions. Of course,  $NE_{limit}$  is a fixed value not altering during the test, but  $NE_{low}$  and  $NE_{high}$  as well as the confidence range CR are altering during the test. For reasons of illustration, however, the three possibilities of the possible positions of the confidence range CR with respect to the constant limit  $NE_{limit}$  are drawn for the same example in Fig. 1.

The above can be described by the following formulas:

10

The current number of samples  $ns$  is calculated from the preliminary Bit Error Ratio  $ber$  and the preliminary number of errors  $ne$

15

$$ber = ne/ns \quad (6)$$

After a full test the final Bit Error Ratio is

20

$$BER_{limit} = NE_{limit} / ns \quad (7)$$

for abbreviation in the formula:

25

$$ber_{norm} = ber/BER_{limit} = ne/NE_{limit} \quad (8)$$

(normalised ber)

Early pass stipulates:

$$NE_{high} < NE_{limit} \quad (9)$$

30

Early fail stipulates:

$$NE_{low} > NE_{limit} \quad (10)$$

Formula for the early pass limit:

35

$$ber_{norm} = \frac{ne}{NE_{high}} \quad (11)$$



This is the lower curve ( $ber_{norm_{pass}}(ne, C)$ ) in Fig. 2, which shows  $ber_{norm}$  as a function of  $ne$ .

Formula for the early fail limit:

5

$$ber_{norm} = \frac{ne}{NE_{low}} \quad (12)$$

This is the upper curve ( $ber_{norm_{fail}}(ne, D)$ ) in Fig. 2.

- 10 As the early pass limit is not defined for  $ne = 0$  (normally the case at the very beginning of the test for a good DUT), an artificial error event with the first sample can be introduced. When the first real error event occurs, the artificial error is replaced by this real one. This gives
- 15 the shortest possible measurement time for an ideal good DUT. For example  $ns=5000$  for  $BER_{limit} = 0.001$  and probability  $D = D_1 = D_2 = 0.2\%$ .

- As the early fail limit uses  $NE_{low} < 1$  for small  $ne < k$  (in
- 20 the example below  $k=5$ ) due to a decision problem at a fractional error, the early fail limit at  $ne=k$  is extended with a vertical line upwards. This ensures that a broken DUT hits the early fail limit in any case after a few samples, approx. 10 in the example. In other words, the
- 25 test is not stopped as long as  $ne$  is smaller than  $k$ .

- With each new sample and/or error a new test is considered, reusing all former results. With each new test the preliminary data for  $ns$ ,  $ne$  and  $ber$  and  $ber_{norm}$  are updated
- 30 and a  $ber_{norm}/ne$  coordinate is entered into the  $ber_{norm}$ -diagram. This is shown in Fig. 3. Once the trajectory crosses the early fail limit ( $ber_{norm}(ne, D)$ ) or the early pass limit ( $ber_{norm}(ne, C)$ ) the test may be stopped and the conclusion of early fail or early pass may be drawn based
- 35 on this instant.

Fig. 3 shows the curves for early fail and early pass.  $ber_{norm}$  is shown as a function of the number of errors  $ne$ .



For the simple example demonstrated in Fig. 3, it is  $BER_{limit} = 0.2 = 1/5$  and the final Bit Error Ratio  $BER = 0.25 (1/4)$ . The test starts with the first bit sample, for which no error is detected. For the second sample, a first error is detected and the preliminary Bit Error Ratio  $ber = ne/ns = 1/2$  and  $ber_{norm} = ber/BER_{limit}$  becomes  $1/2 : 1/5 = 5/2$ .  $ber_{norm}$  after the second sample is marked with a cross a in Fig. 3. For the third, fourth and fifth sample, no further error occurs and  $ber_{norm}$  subsequently becomes  $5/3$ ,  $5/4$  and  $5/5$ , respectively, which is marked with the crosses b, c and d in Fig. 3, respectively. The sixth sample brings a new error and  $ne$  becomes 2. Consequently,  $ber = ne/ns$  becomes  $2/6$  and  $ber_{norm}$  becomes  $10/6$ . This situation is marked with cross e in Fig. 3. For the seventh, eighth and ninth sample, no further error occurs and the situation after the seventh, eighth and ninth sample is marked with crosses f, g, h in Fig. 3, respectively. The tenth sample brings a third error. Consequently,  $ber$  becomes  $3/10$  and  $ber_{norm}$  becomes  $15/10$ . This situation is marked with cross i in Fig. 3. As can be seen from Fig. 3, the trajectory is between the early fail curve and the early pass curve at the beginning of the test, but converges to a line Z, which crosses the early fail curve after about forty errors. After forty errors, it can thus be decided that the tested DUT early fails the test.

If no early stop occurs the BER test may be stopped, after the following condition is valid:

$$ne \geq K \quad (13)$$

and the DUT shall be passed, if  $ns$  is sufficiently high.  $K$  is a maximum number of errors. For example  $K$  can be 200.

If the trajectory neither crosses the early fail curve nor the early pass curve after  $K$  (for example 200) errors have occurred, the DUT can be finally passed. If the DUT, however, is rather good or rather bad, the tests can be



stopped much earlier, long before the  $K = 200$  errors have occurred. This significantly shortens the total test time.

In the above embodiment early fail means: a DUT is failed and a probability of 0.2 % that it is actually better than the limit is accepted. Further early pass means: the DUT is passed and a probability of 0.2 % that it is actually worse than the limit is accepted. If the test is stopped at 200 errors the DUT is passed without any early fail or early pass condition arbitrarily. It can cross the vertical 200 error line in Fig. 2 at different heights, each height is connected with a certain statistical interpretation: The probability to have a DUT better (worse) than the limit is indicated in Fig. 5. The vertical in Fig. 5 shows the position in Fig. 2 at the end of the test. The horizontal in Fig. 5 shows the respective probability.

This embodiment contains a pseudo paradox, due to statistical nature of the test and limited test time, demonstrated with the following example: A DUT, which is early failed, would pass if the probability for a wrong decision has been reduced by widening the early stop limits, or vice versa, if the test is stopped at 200 errors and the DUT is arbitrarily failed. A DUT, which is early passed, would fail if the probability for a wrong decision has been reduced.

The following embodiment resolves this pseudo paradox and additionally accelerates the test. This is done by a meaningful redefinition of the early pass limit maintaining the early fail limit. Early pass means now: A DUT is passed and a probability of 0.2 % that it is actually worse than  $M$  times the specified limit ( $M > 1$ ) is accepted. This is a worse DUT limit. This shifts the early pass limit upwards in Fig. 2 as shown in Fig. 4.  $Bernorm_{pass}(ne, C)$  in Fig. 2 becomes  $bernorm_{bad_{pass}}(ne, C)$  in Fig. 4.  $Bernorm_{fail}(ne, D)$  remains unchanged. Now it is

$$NE_{limit, M} = BER_{limit} \cdot M \cdot ns \quad (14)$$



and an early pass is allowed, if  $NE_{limit} \cdot M = NE_{limit,M} > NE_{high}$ .

- 5 There are three high level parameters for the test:
- Probability to make a wrong decision (proposal:  $C = 0.2 \%$ )
  - Final stop (proposal:  $K = 200$  errors)
  - Definition of a Bad DUT ( $BER_{limit} \cdot M$ )
- 10 These parameters are interdependent. It is possible to enter two of them and to calculate the third one. To make the test transparent, it is proposed to enter the wrong decision probability  $C$  and the final stop condition  $K$  and to derive the Bad DUT factor  $M$ . This is done in the
- 15 following manner: The early pass limit is shifted upwards by a factor of  $M$ , such that the early fail and the early pass limit intersect at 200 errors in the example as shown in Fig. 4. Fig. 4 also shows the test limit obtained from the crossing point from the early fail curve and the easy
- 20 pass curve, corresponding to  $M_{test}$ .

There are infinite possibilities to resolve the above mentioned paradox.

- 25 In the example above the open end between the limits was originally declared pass, and time was saved by multiplying the early pass limit with  $M$  ( $M > 1$ ), shifting it upwards such that the early fail and the early pass curve intersect at 200 errors (200: example from above). Such only a DUT, bad
- 30 with high probability, is failed (customer risk).

- The complementary method is: The open end between the limits is declared fail, and time is saved by multiplying the early fail limit with  $m$  ( $0 < m < 1$ ), shifting it downwards,
- 35 such that the early fail and the early pass curve intersect at 200 errors (200: example from above). Such only a DUT, good with high probability, is passed (manufacturer risk).



The compromise method is: The open end between the limits is partitioned in any ratio: the upper part is declared fail and the lower part is declared pass. Time is saved by multiplying the early fail limit with  $m$  ( $0 < m < 1$ ) and such shifting it downwards and by multiplying the early pass limit with  $M$  ( $M > 1$ ) and such shifting it upwards. So the early fail and the early pass curve intersect at 200 errors (200: example from above).

- 10 With given  $D_1$  and  $D_2$  the early fail curve and the early pass curves in Fig. 3 and Fig. 2 or Fig. 4 can be calculated before the test is started. During the test only  $ber_{norm} = ne/NE_{limit}$  has to be calculated and to be compared with the early pass limit and the early fail limit as explained with respect to Fig. 3 and Fig. 4. Thus, no intensive calculation has to be done during the test.
- 15



## Claims

1. Method for testing the Error Ratio BER of a device  
5 against a maximal allowable Error Ratio  $BER_{limit}$  with an early pass criterion, whereby the early pass criterion is allowed to be wrong only by a small probability  $D_1$ , with the following steps

- measuring  $ns$  bits of the output of the device, thereby  
10 detecting  $ne$  erroneous bits of these  $ns$  bits,
- assuming that the likelihood distribution giving the distribution of the number of erroneous bits  $ni$  in a fixed number of samples of bits is  $PD(NE, ni)$ , wherein  $NE$  is the average number of erroneous bits, obtaining  $PD_{high}$  from

15

$$D_1 = \int_0^{ne} PD_{high}(NE_{high}, ni) dni$$

wherein  $PD_{high}$  is the worst possible likelihood distribution  
containing the measured  $ne$  erroneous bits with the  
20 probability  $D_1$ ,

- obtaining the average number of erroneous bits  $NE_{high}$  for the worst possible likelihood distribution  $PD_{high}$ ,
- comparing  $NE_{high}$  with  $NE_{limit} = BER_{limit} \cdot ns$ ,
- if  $NE_{limit}$  is higher than  $NE_{high}$  stopping the test and  
25 deciding that the device has early passed the test and
- if  $NE_{limit}$  is smaller than  $NE_{high}$  continuing the test whereby increasing  $ns$ .

2. Method for testing the Error Ratio BER according to  
30 claim 1,

**characterized in that**

the likelihood distribution  $PD(NE, ni)$  is the Poisson distribution.

35 3. Method for testing the Error Ratio BER according to claim 1 or 2,

**characterized in that**



for avoiding a undefined situation for  $ne=0$  starting the test with an artificial error  $ne=1$  not incrementing  $ne$  then a first error occurs.

- 5 4. Method for testing the Error Ratio BER of a device against a maximal allowable Error Ratio  $BER_{limit}$  with an early fail criterion, whereby the early fail criterion is allowed to be wrong only by a small probability  $D_2$ , with the following steps
- 10 - measuring  $ns$  bits of the output of the device, thereby detecting  $ne$  erroneous bits of these  $ns$  bits,  
 - assuming that the likelihood distribution giving the distribution of the number of erroneous bits  $ni$  in a fixed number of samples of bits is  $PD(NE,ni)$ , wherein  $NE$  is the
- 15 average number of erroneous bits, obtaining  $PD_{low}$  from the

$$D_2 = \int_{ne}^{\infty} PD_{low}(NE_{low}, ni) dni$$

- wherein  $PD_{low}$  is the best possible likelihood distribution
- 20 containing the measured  $ne$  erroneous bits with the probability  $D_2$ ,
- obtaining the average number of erroneous bits  $NE_{low}$  for the best possible likelihood distribution  $PD_{low}$ ,
- comparing  $NE_{low}$  with  $NE_{limit} = BER_{limit} \cdot ns$ ,
- 25 - if  $NE_{limit}$  is smaller than  $NE_{low}$  stopping the test and deciding that the device has early failed the test and
- if  $NE_{limit}$  is higher than  $NE_{low}$  continuing the test whereby increasing  $ns$ .

- 30 5. Method for testing the Error Ratio BER according to claim 4,  
 characterized in that  
 the likelihood distribution  $PD(NE,ni)$  is the Poisson distribution.

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6. Method for testing the Error Ratio BER according to claim 4 or 5,  
 characterized in that



for avoiding a undefined situation for  $ne < k$ , wherein  $k$  is a small number of errors, not stopping the test as long as  $ne$  is smaller than  $k$ .

- 5    7. Method for testing the Error Ratio BER according to claim 6,  
characterized in that  
 $k$  is 5.

- 10   8. Method for testing the Error Ratio BER according to any of claims 4 to 7,  
characterized by  
an additional early pass criterion, whereby the early pass  
criterion is allowed to be wrong only by a small  
15   probability  $D_1$ , with the following additional steps  
- assuming that the likelihood distribution giving the  
distribution of the number of erroneous bits  $ni$  in a fixed  
number of samples of bits is  $PD(NE, ni)$ , wherein  $NE$  is the  
average number of erroneous bits, obtaining  $PD_{high}$  from

20

$$D_1 = \int_0^{ne} PD_{high}(NE_{high}, ni) dni$$

- wherein  $PD_{high}$  is the worst possible likelihood distribution containing the measured  $ne$  erroneous bits with the  
25   probability  $D_1$ ,

- obtaining the average number of erroneous bits  $NE_{high}$  for the worst possible likelihood distribution  $PD_{high}$ ,  
- comparing  $NE_{high}$  with  $NE_{limit} = BER_{limit} \cdot ns$ ,  
- if  $NE_{limit}$  is higher than  $NE_{high}$  stopping the test and  
30   deciding that the device has early passed the test and  
- if  $NE_{limit}$  is smaller than  $NE_{high}$  continuing the test, whereby increasing  $ns$ .

9. Method for testing the Error Ratio BER according to  
35   claim 8,  
characterized in that



for avoiding a undefined situation for  $ne=0$  starting the test with an artificial error  $ne=1$  not incrementing  $ne$  then a first error occurs.

- 5 10. Method for testing the Error Ratio BER according to claim 8 or 9,  
 characterized in that  
 the probability  $D_1$  for the wrong early pass criterion and  
 the probability  $D_2$  for the wrong early fail criterion are  
 10 equal ( $D_1=D_2$ ).

11. Method for testing the Error Ratio BER according to any of claims 4 to 7,  
 characterized by  
 15 an additional early pass criterion, whereby the early pass criterion is allowed to be wrong only by a small probability  $D_1$ , with the following additional steps  
 - assuming that the likelihood distribution giving the distribution of the number of erroneous bits  $ni$  in a fixed  
 20 number of samples of bits is  $PD(NE,ni)$ , wherein  $NE$  is the average number of erroneous bits, obtaining  $PD_{high}$  from

$$D_1 = \int_0^{ne} PD_{high}(NE_{high}, ni) dni$$

- 25 wherein  $PD_{high}$  is the worst possible likelihood distribution containing the measured  $ne$  erroneous bits with the probability  $D_1$ ,  
 - obtaining the average number of erroneous bits  $NE_{high}$  for the worst possible likelihood distribution  $PD_{high}$ ,  
 30 - comparing  $NE_{high}$  with  $NE_{limit,M} = BER_{limit} \cdot M \cdot ns$ , with  $M > 1$   
 - if  $NE_{limit,M}$  is higher than  $NE_{high}$  stopping the test and deciding that the device has early passed the test and  
 - if  $NE_{limit,M}$  is smaller than  $NE_{high}$  continuing the test,  
 35 whereby increasing  $ns$ .



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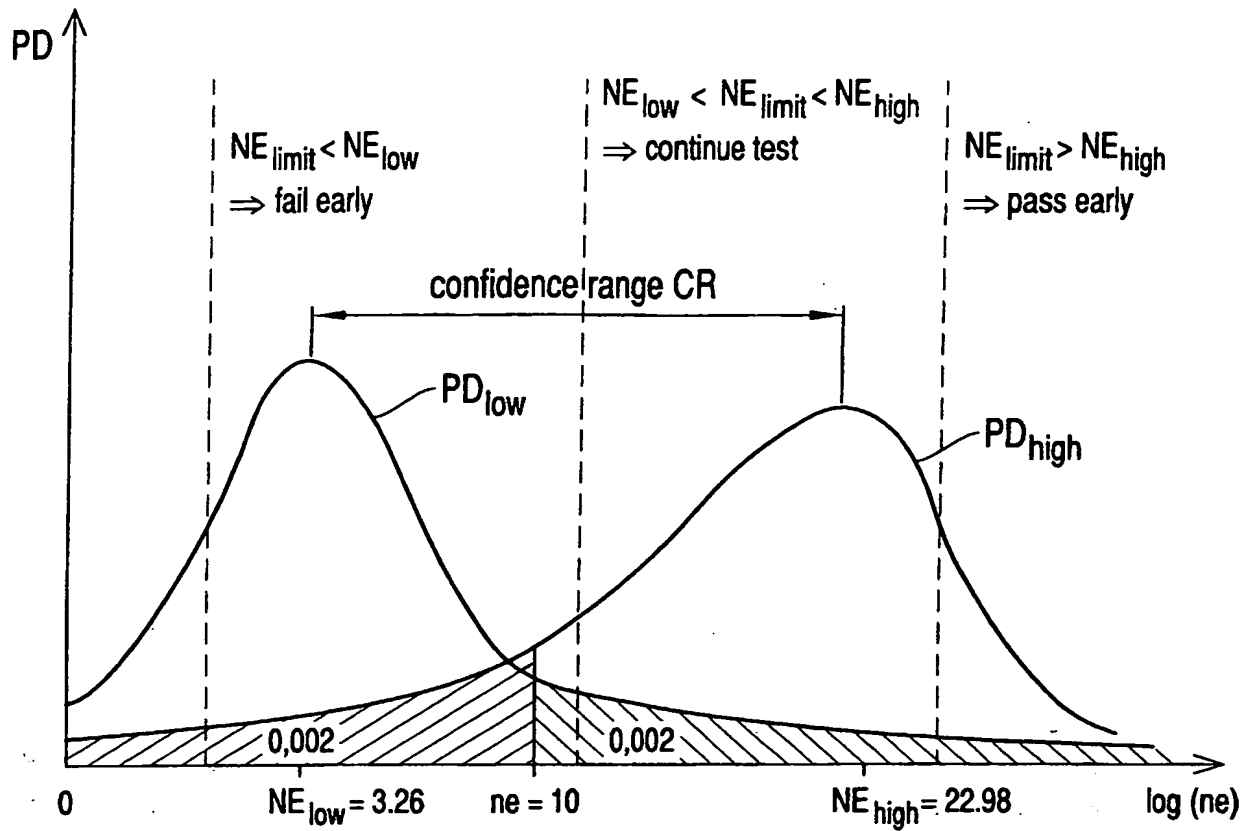


Fig. 1

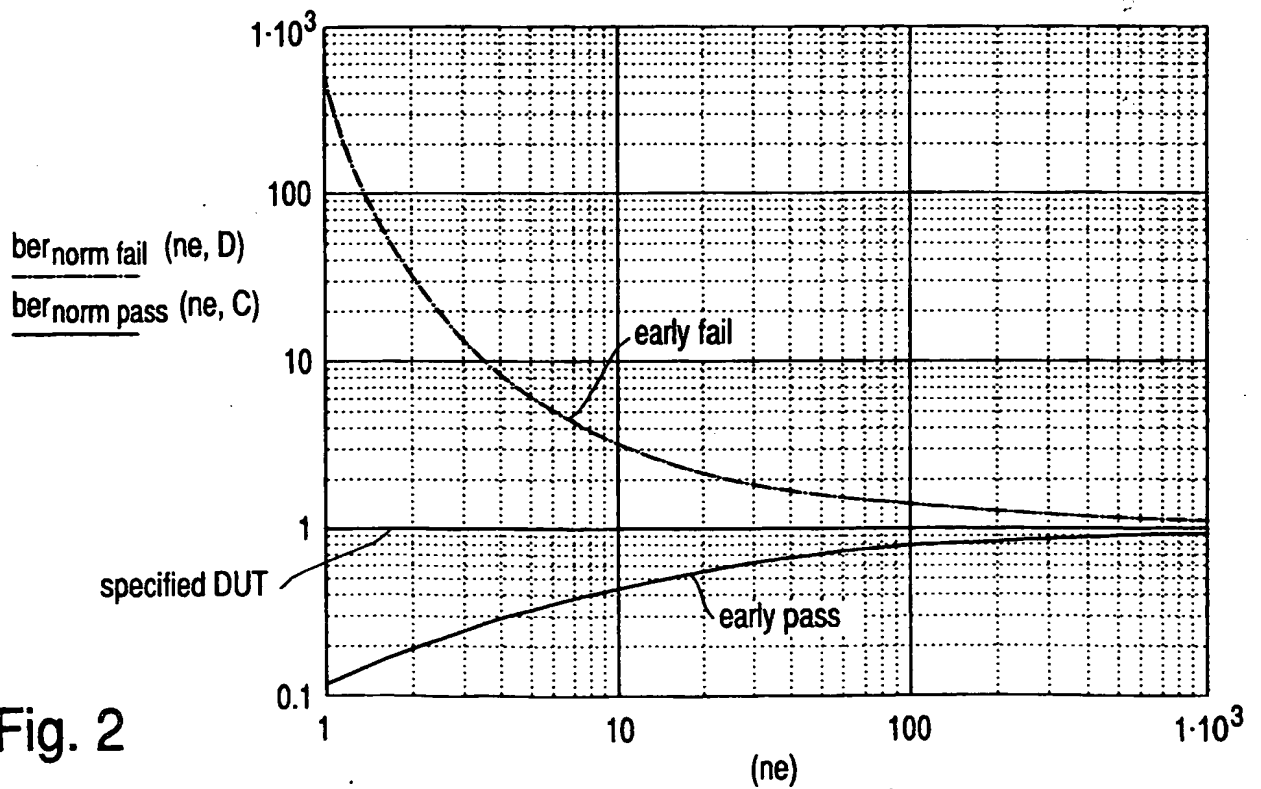


Fig. 2



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BER limit = 0.2 (1/5) Actual BER = 0.25 (1/4)

Number of sample,	1	2	3	4	5	6	7	8	9	10 etc...
Sequence, 0: correct, 1: error	0	1	0	0	0	1	0	0	0	1
BER		1/2	1/3	1/4	1/5	2/6	2/7	2/8	2/9	3/10
BER <sub>norm</sub>		5/2	5/3	5/4	5/5	10/6	10/7	10/8	10/9	15/10

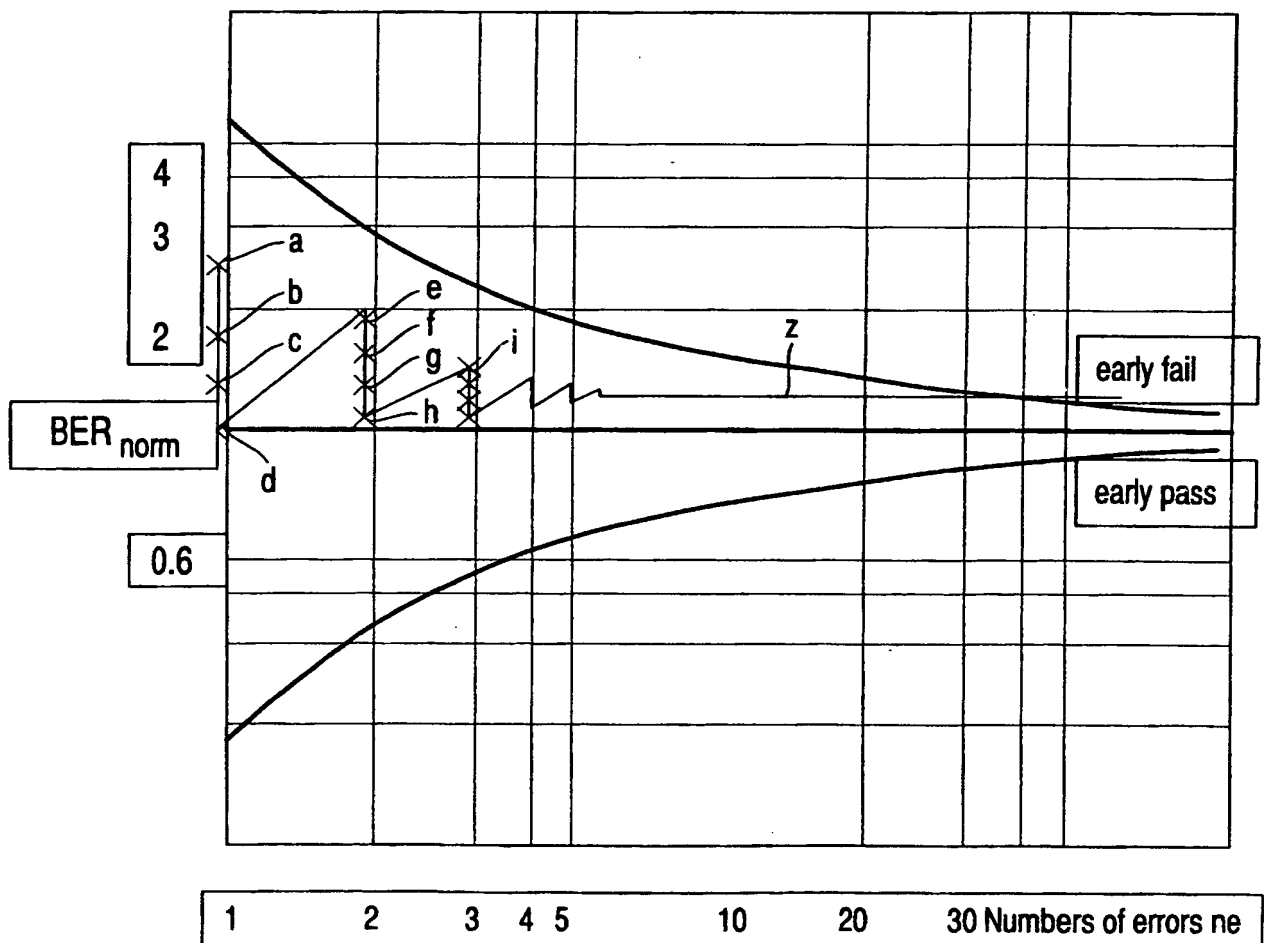


Fig. 3



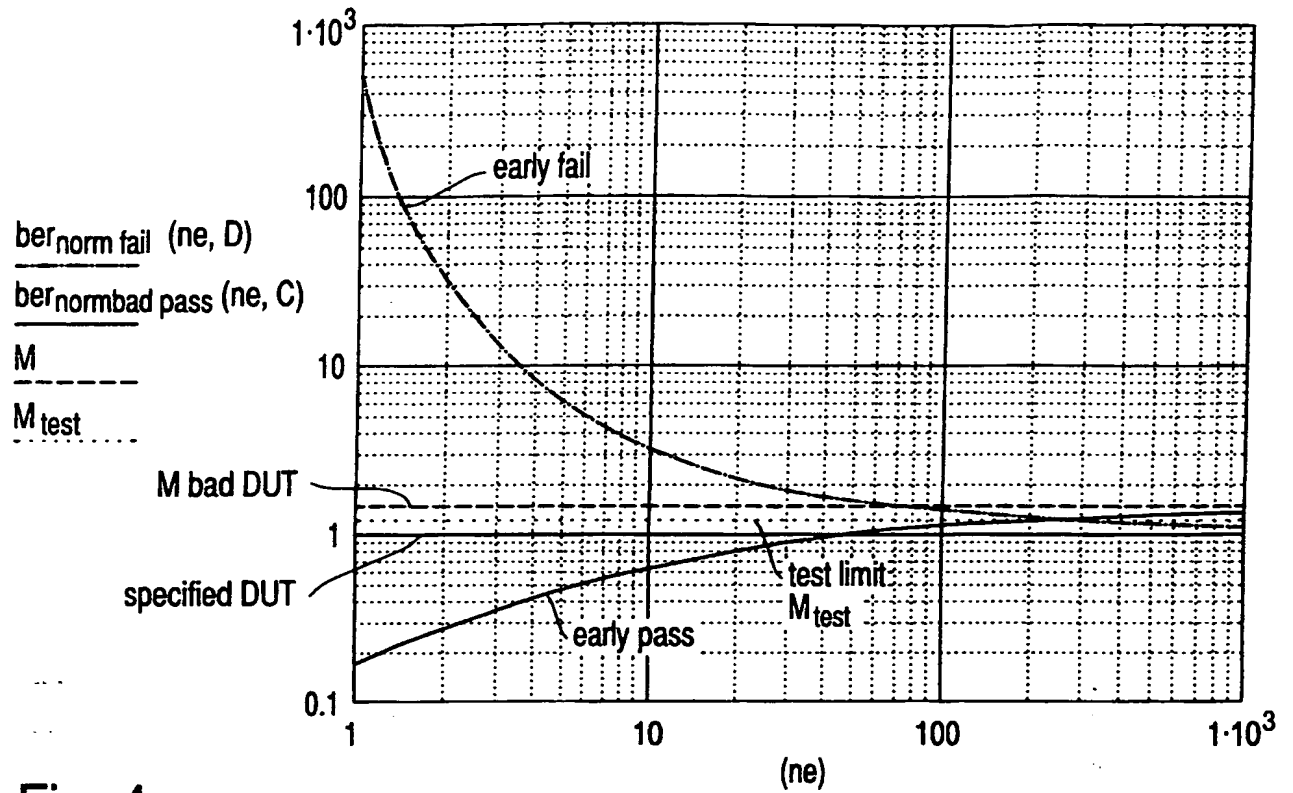


Fig. 4

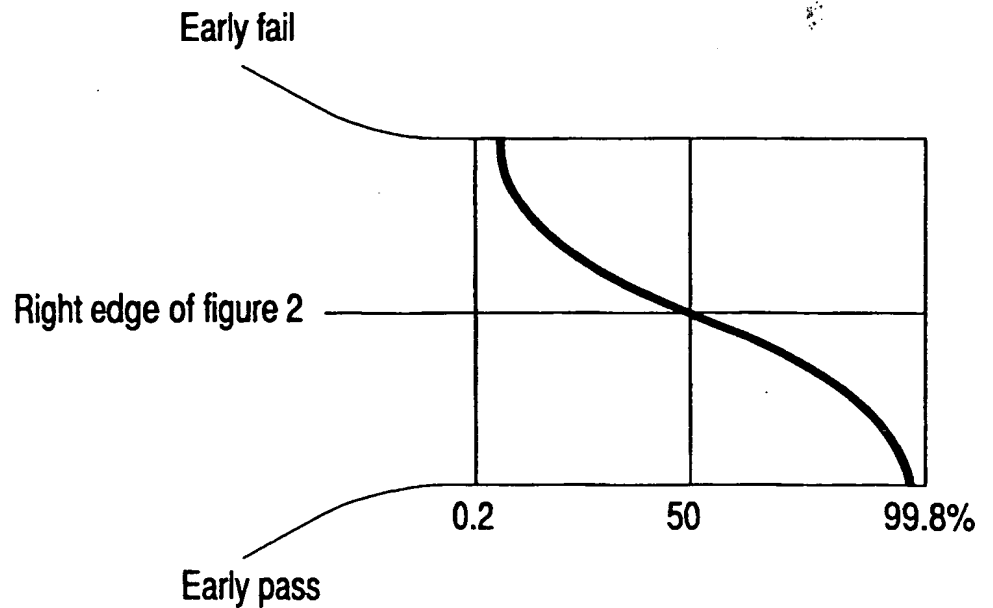


Fig. 5



## INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/02252

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04L1/24 H04B17/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04L H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 606 563 A (LEE CHRIS E ET AL) 25 February 1997 (1997-02-25) * abstract * column 1, line 41 - line 56 column 2, line 31 - column 3, line 16 column 3, line 31 - line 54 figures 1,2	1,4
A	EP 0 954 117 A (ICO SERVICES LTD) 3 November 1999 (1999-11-03) * abstract * column 3, line 27 - column 4, line 19 column 10, line 11 - line 40 figure 7	1,4

☐ Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

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**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International Application No  
**PCT/EP 02/02252**

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			JP	2000059862 A	25-02-2000



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